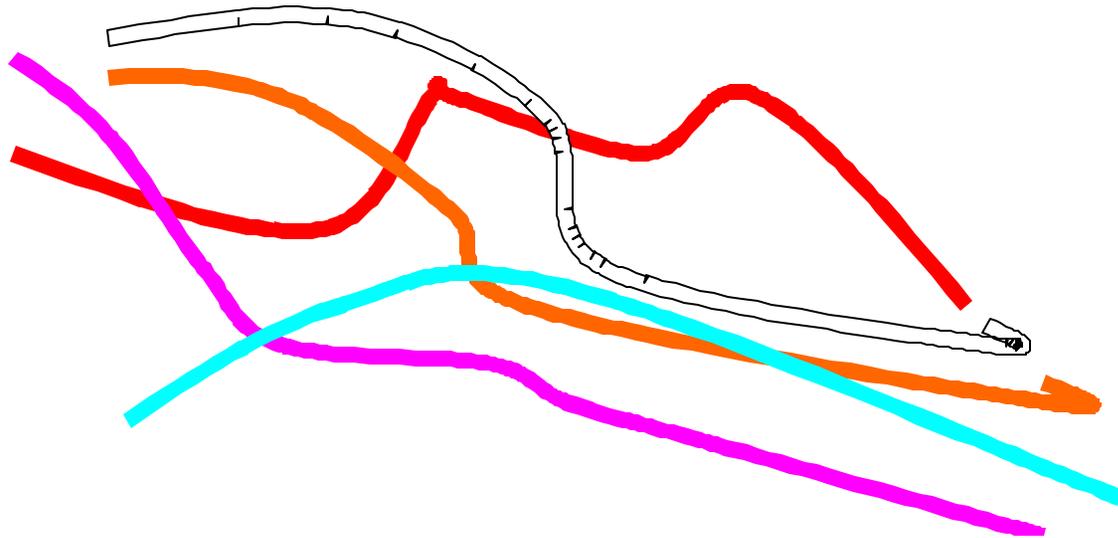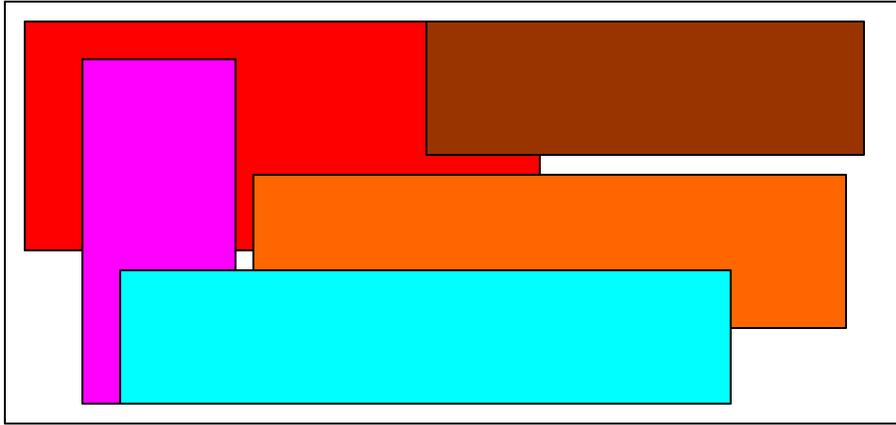# A Combinatorial Auction Designed for the Federal Communications Commission

Charles R. Plott

California Institute of Technology
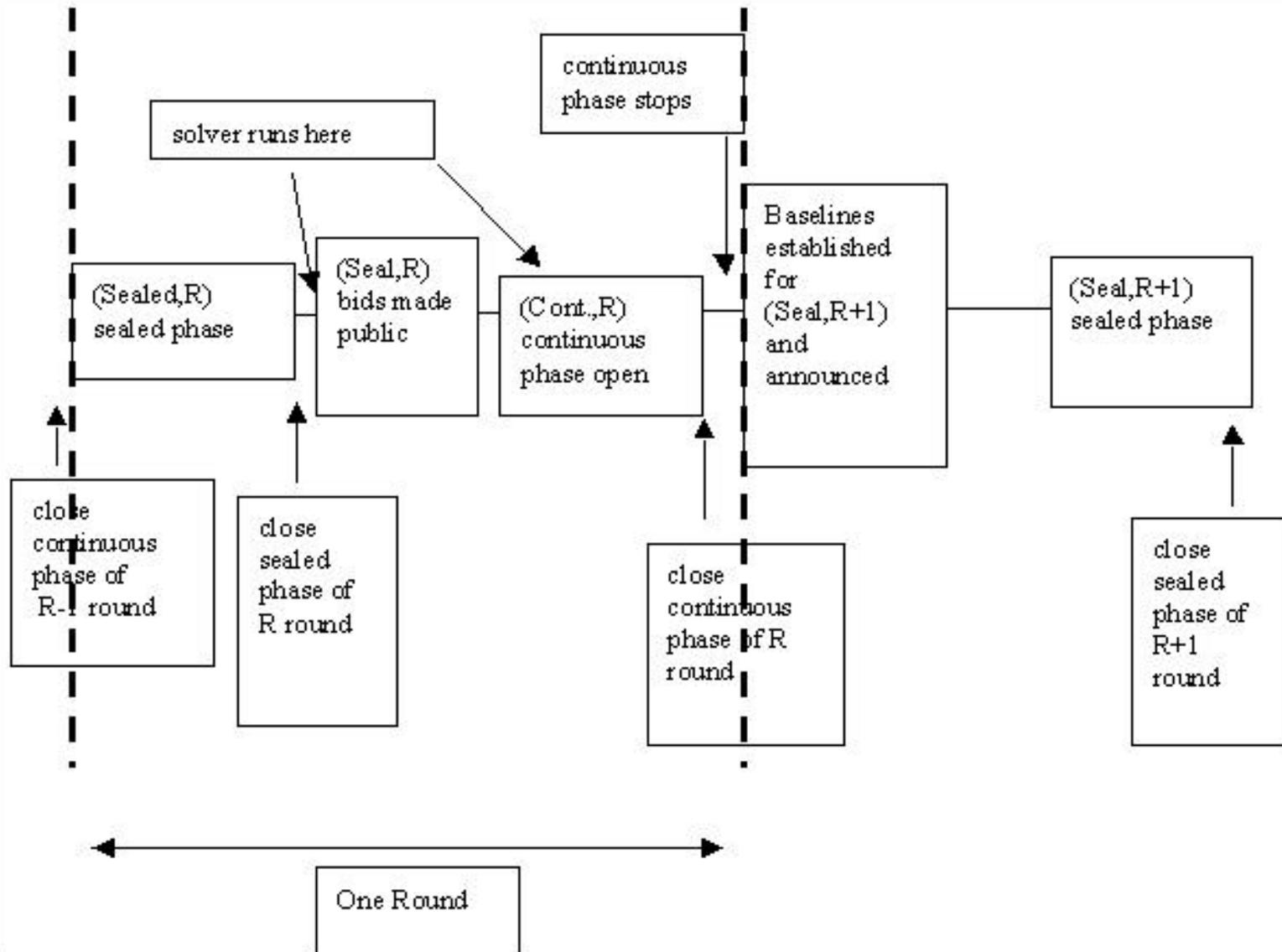
ID: 1 Round: 1, Phase: 2 (Continuous)   Time Remaining: No Timer   **Reload Sign Off**

continuous phase stops

solver runs here

(Sealed,R) sealed phase

(Seal,R) bids made public

(Cont.,R) continuous phase open

Baselines established for (Seal,R+1) and announced

(Seal,R+1) sealed phase

close continuous phase of R-1 round

close sealed phase of R round

close continuous phase of R round

close sealed phase of R+1 round

One Round

Eligibility t = λ min [Activity t-1, Eligibility t-1]

max   Activity in sealed bid phase
       Activity in continuous phase

Eligibility $\geq$ Σ bidding units on item j
         all items j
         bid as
         singleton

EXPOSURE
LIMITS

Eligibility $\geq$ Σ Σ bidding units on item j
         all bids   j $\in$ K
         K with
         two or
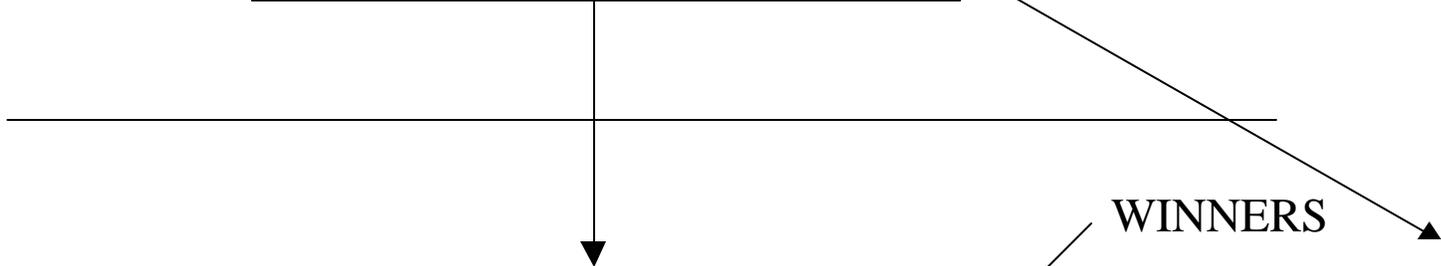   more
         items

POSITIONING
INCENTIVES

SPEED PARAMETERS

INCREMENT REQUIREMENTS - A BID WHEN PLACED MUST BE X%
ABOVE THE MAXIMUM COVER

$$ACTIVITY = \beta_1 \text{ WINNING BIDS BIDDING POINTS}$$
$$+$$
$$\beta_2 \text{ WINNING LEVEL BIDS}$$
$$+$$
$$\beta_3 \text{ ABOVE MAX OF SINGLES}$$
$$+$$
$$\beta_4 \text{ BELOW MAX OF SINGLES}$$

AGGRESSIVE BIDS
COUNT FOR MORE
ACTIVITY

MEASUREMENTS HERE

ROUND

WINNERS

ABCD 100

BC 20

A 40
B   5
C 10
D 15

ABC 100
D 15

ABCD 100   ← ABOVE MIN WIN
AD 85

BCD 50   ABOVE
BC 20   VALUE OF
A40   SINGLES
B 10
C10

B 5   BELOW

Bidder (revealed) ID: [ ]

Bid Price: [ ]

	License			License		
loc.	1	2	loc.	1	2
A	☐	☐	a	☐	☐
B	☐	☐	b	☐	☐
C	☐	☑	c	☐	☐
D	☐	☑	d	☐	☐
E	☐	☑	e	☐	☐
F	☑	☐	f	☐	☐
G	☐	☐	g	☐	☐
H	☐	☐	h	☐	☐
I	☐	☐	i	☐	☐
J	☐	☐	j	☐	☐
K	☐	☐	k	☐	☐

Query Submitted

Your query has been submitted.

Total Revenue: 1149

	Winning Bids (Bid Number)						Best Single Item Bids (by Amount)						Approximate Item Prices		
	license			license			license			license			license		
location	1	2	loc.	1	2	loc.	1	2	loc.	1	2	loc.	1	2
A	55	10	a	110		A	15	2	a			A	16	2
B	55		b		40	B	3		b			B	56	0
C	55	57	c	10	40	C	18	15	c	132		C	21	15
D	55	55	d	40		D	41		d			D	43	59
E			e		110	E			e			E	0	0
F	40		f		40	F			f			F	38	0
G			g	40	110	G			g			G	0	0
H	55		h		110	H			h			H	105	0
I			i			I			i			I	0	0
J	27		j			J	5		j			J	5	0
K		40	k			K		2	k			K	0	2
L			l			L			l			L	0	0
M			m	110	40	M			m			M	0	0
N			n			N			n			N	0	0
O		40	o			O			o			O	0	0
P			p	40	10	P			p			P	0	0
Q			q	10	40	Q			q			Q	0	0

	w		
	x	☐	☐
	y	☐	☐

Clear Bid	Send Query
ersecting Bids	Redemption Value

n be used to:

t a new bid
an existing bid
the minimum price for a bid

y Submitted

has been submitted

D2 E2 F1

represents **400** bidding units

is needed to satisfy the increment requirements for this

5 is required to provisionally win this package

is bid as winning

Y	40	**y**	110	40		Y		**y**			Y	0		**y**	0	0
Z		40				**Z**					**Z**	0	0			

bid ID	r p - bid#	price	bids	time entered
55	1 2 - 1047	300	A1 B1 C1 D1 D2 H1	Sat Jan 22 11:21:01 20
10	1 2 - 1046	41	D1	Tue Jan 18 12:27:36 20
10	1 2 - 1045	2	K2	Tue Jan 18 12:21:23 20
10	1 2 - 1043	132	c1	Mon Jan 17 14:02:57 2
10	1 2 - 1042	16	A1 B2	Mon Jan 17 14:00:23 2
23	1 2 - 1040	120	C1 D1 D2	Tue Jan 11 14:00:57 20
36	1 2 - 1039	18	C1	Tue Jan 11 13:53:27 20
23	1 2 - 1038	15	A1	Tue Jan 11 13:50:10 20
80	1 2 - 1037	74	D1 E1 F1	Fri Dec 17 13:43:13 19
27	1 2 - 1035	59	D2 E2 F2	Sun Dec 12 15:13:19 1
27	1 2 - 1034	5	J1	Sun Dec 12 15:10:08 1
59	1 2 - 1033	100	C1 D1 D2	Sun Dec 12 13:34:17 1
57	1 2 - 1032	15	C2	Sun Dec 12 13:29:18 1
42	1 2 - 1031	137	B1 B2 D1 E1 F1	Fri Dec 3 17:34:06 199
55	1 2 - 1030	103	G1 G2 H1 H2	Fri Dec 3 17:30:35 199
45	1 2 - 1029	2	G2 H1 I1	Fri Dec 3 15:32:41 199
44	1 2 - 1027	238	B1 B2 D1 E1 F1 G1 H1	Fri Dec 3 15:26:21 199
33	1 2 - 1026	186	C1 D1 E1 F1 F2	Fri Dec 3 11:34:14 199
14	1 2 - 1024	105	F2 G2 H1 I1	Wed Nov 17 11:01:16
25	1 2 - 1023	3	B1	Wed Oct 6 09:32:37 1!
22	1 2 - 1022	385	b1 b2 c1 c2 d2	Wed Oct 6 09:28:52 1!
49	1 2 - 1021	46	D1 D2 E1 F2	Thu Sep 23 12:36:53 1
14	1 2 - 1020	382	c1 d1 e1	Fri Sep 17 09:36:33 19

ID: 3   **Round: 1, Phase: 2 (Continuous)**   Time Remaining: `No Timer`   **Reload**   **S**

	License			License	
loc.	1	2	loc.	1	2
A	☐	☐	a	☐	☐
B	☐	☐	b	☐	☐
C	☐	☑	c	☐	☐
D	☐	☑	d	☐	☐
E	☐	☑	e	☐	☐
F	☑	☐	f	☐	☐
G	☐	☐	g	☐	☐
H	☐	☐	h	☐	☐

Query Submitted

Your query has been submitted

Package: C2 D2 E2 F1
The package represents **400** bidding units
A Price of **16** is needed to satisfy the increment requirements for this package
A Price of **135** is required to provisionally win this package

[Show this bid as winning]

Round: 1, Phase: 2 (Continuous Bid Phase)

Total Revenue: 1149

Winning Bids (Bid Number)

	license			license	
location	1	2	loc.	1	2
A	10	10	a	110	
B	25	10	b		40
C	36	-	c	10	40
D	10	-	d	40	
E		-	e		110
F	-	40	f		40
G	55	55	g	40	110
H	55	55	h		110
I			i		
J	27		j		
K		40	k		
L			l		
M			m	110	40
N			n		
O	40		o		
P			p	40	10
Q			q	10	40

Best Single Item Bids (by Amount)

	license			license	
loc.	1	2	loc.	1	2
A	15	2	a		
B	3		b		
C	18	15	c	132	
D	41		d		
E			e		
F			f		
G			g		
H			h		
I			i		
J	5		j		
K		2	k		
L			l		
M			m		
N			n		
O			o		
P			p		
Q			q		

	License	
loc.	1	2
a	☐	☐
b	☐	☐
c	☐	☐
d	☐	☐
e	☐	☐
f	☐	☐
g	☐	☐
h	☐	☐

X	40	x	10	X		x	
Y		40	y	110	40	Y		y
Z		40				Z	

bid ID	r p - bid#	price	bids	time entered
-	- - -	135	C2 D2 E2 F1	-
55	1 2 - 1047	300	A1 B1 C1 D1 D2 H1	Sat Jan 22 11:21:01 20
10	1 2 - 1046	41	D1	Tue Jan 18 12:27:36 20
10	1 2 - 1045	2	K2	Tue Jan 18 12:21:23 20
10	1 2 - 1043	132	c1	Mon Jan 17 14:02:57 2
10	1 2 - 1042	16	A1 B2	Mon Jan 17 14:00:23 2
23	1 2 - 1040	120	C1 D1 D2	Tue Jan 11 14:00:57 20
36	1 2 - 1039	18	C1	Tue Jan 11 13:53:27 20
23	1 2 - 1038	15	A1	Tue Jan 11 13:50:10 20
80	1 2 - 1037	74	D1 E1 F1	Fri Dec 17 13:43:13 19
27	1 2 - 1035	59	D2 E2 F2	Sun Dec 12 15:13:19 1
27	1 2 - 1034	5	J1	Sun Dec 12 15:10:08 1
59	1 2 - 1033	100	C1 D1 D2	Sun Dec 12 13:34:17 1
57	1 2 - 1032	15	C2	Sun Dec 12 13:29:18 1
42	1 2 - 1031	137	B1 B2 D1 E1 F1	Fri Dec 3 17:34:06 199
55	1 2 - 1030	103	G1 G2 H1 H2	Fri Dec 3 17:30:35 199
45	1 2 - 1029	2	G2 H1 I1	Fri Dec 3 15:32:41 199
44	1 2 - 1027	238	B1 B2 D1 E1 F1 G1 H1	Fri Dec 3 15:26:21 199
33	1 2 - 1026	186	C1 D1 E1 F1 F2	Fri Dec 3 11:34:14 199
14	1 2 - 1024	105	F2 G2 H1 I1	Wed Nov 17 11:01:16
25	1 2 - 1023	3	B1	Wed Oct 6 09:32:37 1
22	1 2 - 1022	385	b1 b2 c1 c2 d2	Wed Oct 6 09:28:52 1

Submitted

has been submitted

D2 E2 F1
represents **400** bidding units
is needed to satisfy the increment requirements for this

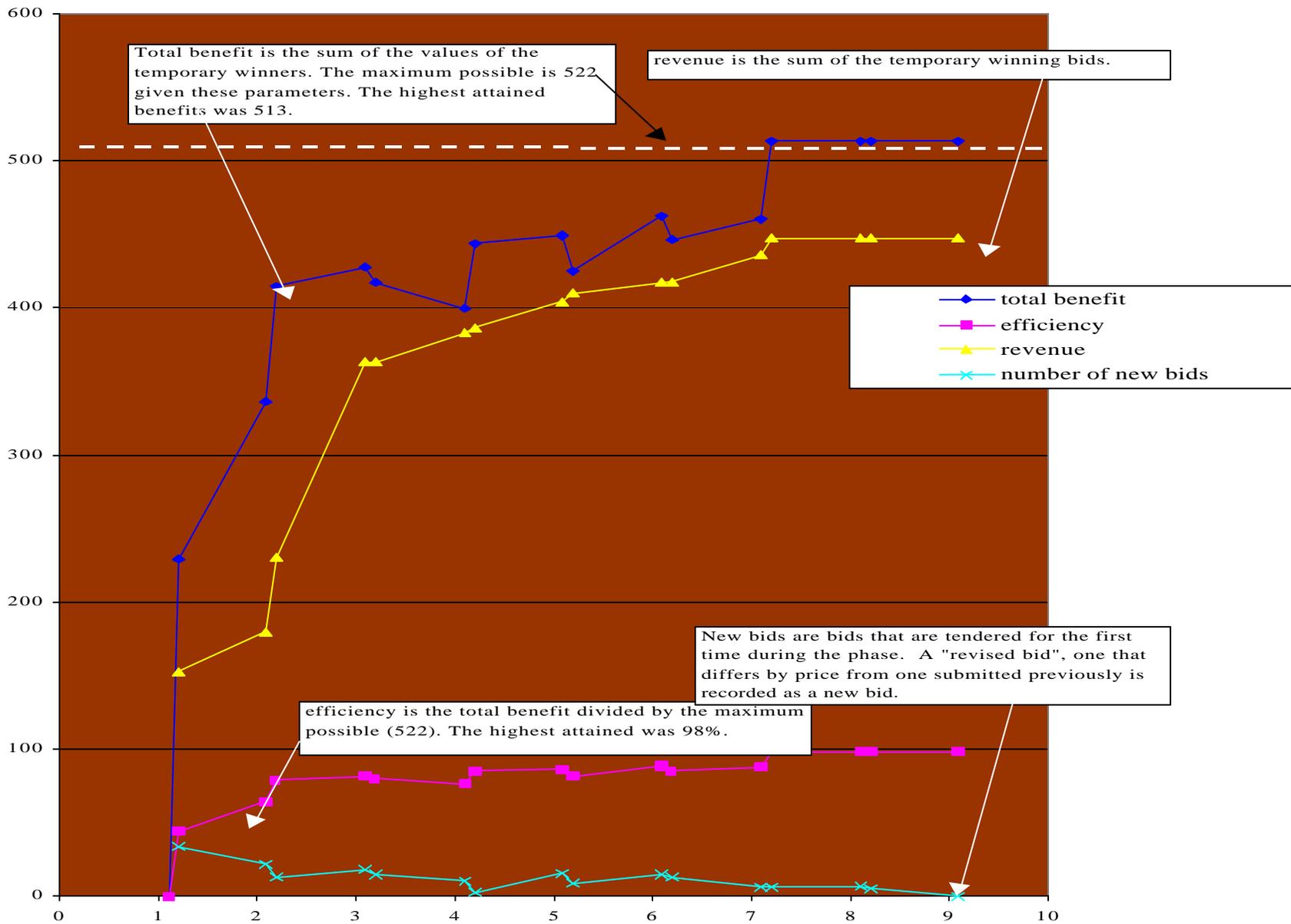5 is required to provisionally win this package

is bid as winning

DOES IT WORK?

Proof of Concept: Efficiency

Design Consistency: ?

Total benefit is the sum of the values of the temporary winners. The maximum possible is 522 given these parameters. The highest attained benefits was 513.

revenue is the sum of the temporary winning bids.

total benefit
efficiency
revenue
number of new bids

New bids are bids that are tendered for the first time during the phase. A "revised bid", one that differs by price from one submitted previously is recorded as a new bid.

efficiency is the total benefit divided by the maximum possible (522). The highest attained was 98%.

The colors represent bidders and not whether a package is involved.

A	B	C	D	E	F
G	H	I	J	K	L

← first best 100% efficiency

A	B	C	D	E	F
G	H	I	J	K	L

← Actual outcome at 98% efficiency. The inefficiency is due to misallocations of the second six items, which are of low value. Only I and K are in the wrong hands.

ID: 1   Round: 9, Phase: 1 (Sealed)   Time Remaining: `0`   **Reload**   **Sign Off**

loc.	License 1	loc.	License 1
A	☐	a	☐
B	☐	b	☐
C	☐	c	☐
D	☐	d	☐
E	☐	e	☐
F	☐	f	☐
G	☐	g	☐
H	☐	h	☐
I	☐	i	☐
J	☐	j	☐
K	☐	k	☐
L	☐	l	☐
M	☐	m	☐
N	☐	n	☐
O	☐	o	☐
P	☐	p	☐

Markets

Markets	Personal Bid Status	Morgue	Redemption Values
Instructions	Help	Rules	Announcements

Total Revenue: 1298

Winning Bids (Bid Number)

location	license 1	loc.	license 1
A	10	a	40
B	10	b	40
C	20	c	40
D	20	d	70
E	50	e	20
F	10	f	40
G	30	g	40
H	60	h	80
I	80	i	80

Best Single Item Bids (by Amount)

loc.	license 1	loc.	license 1
A	10	a	29
B	14	b	16
C	13	c	29
D	13	d	30
E	24	e	44
F	14	f	29
G	19	g	5
H	19	h	30
I	52	i	6

Approximate Item Prices

loc.	license 1	loc.	
A	13	a	
B	14	b	
C	13	c	
D	52	d	
E	24	e	
F	121	f	
G	29	g	
H	29	h	
I	52	i	

Document: Done

19990625-2

990605-2
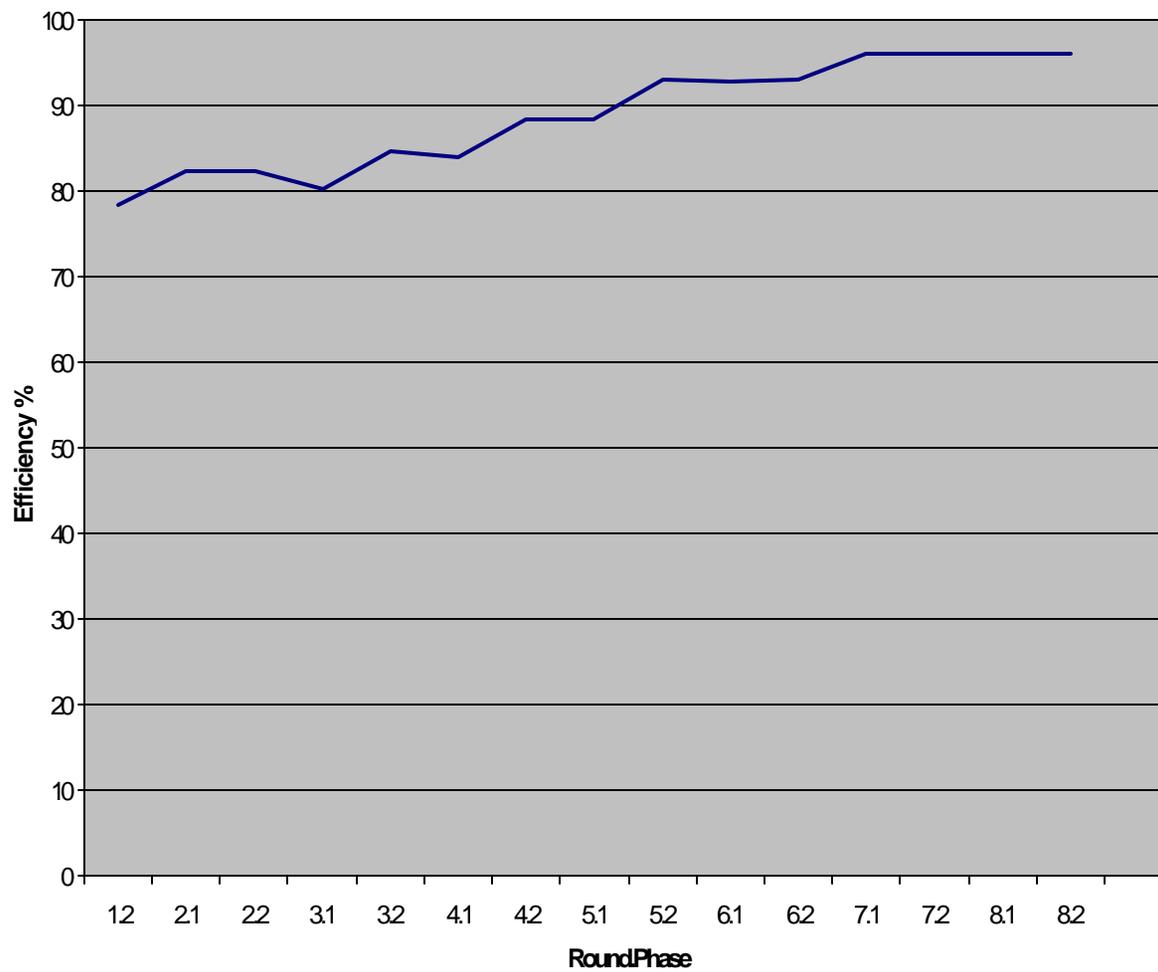
34 items 8 people package
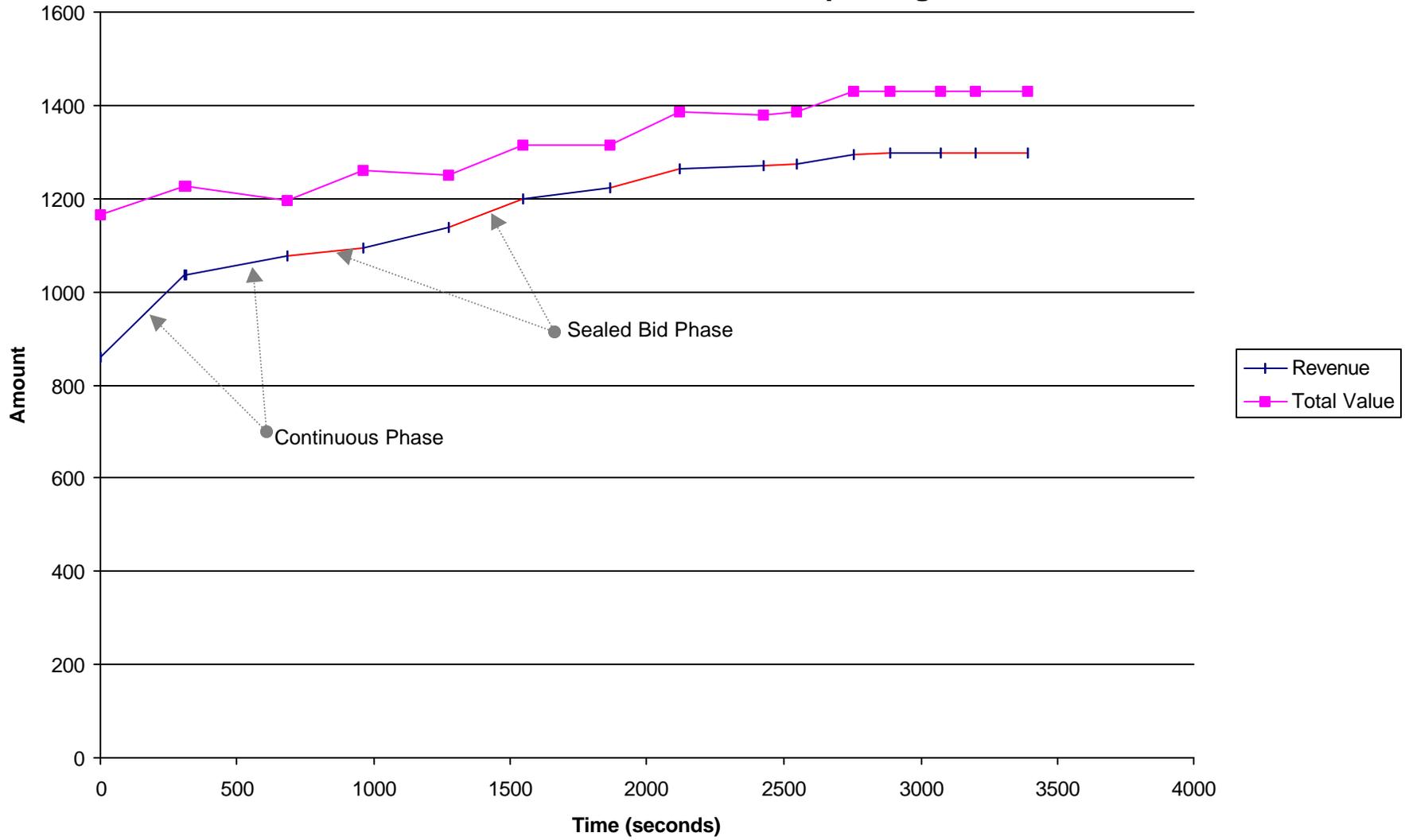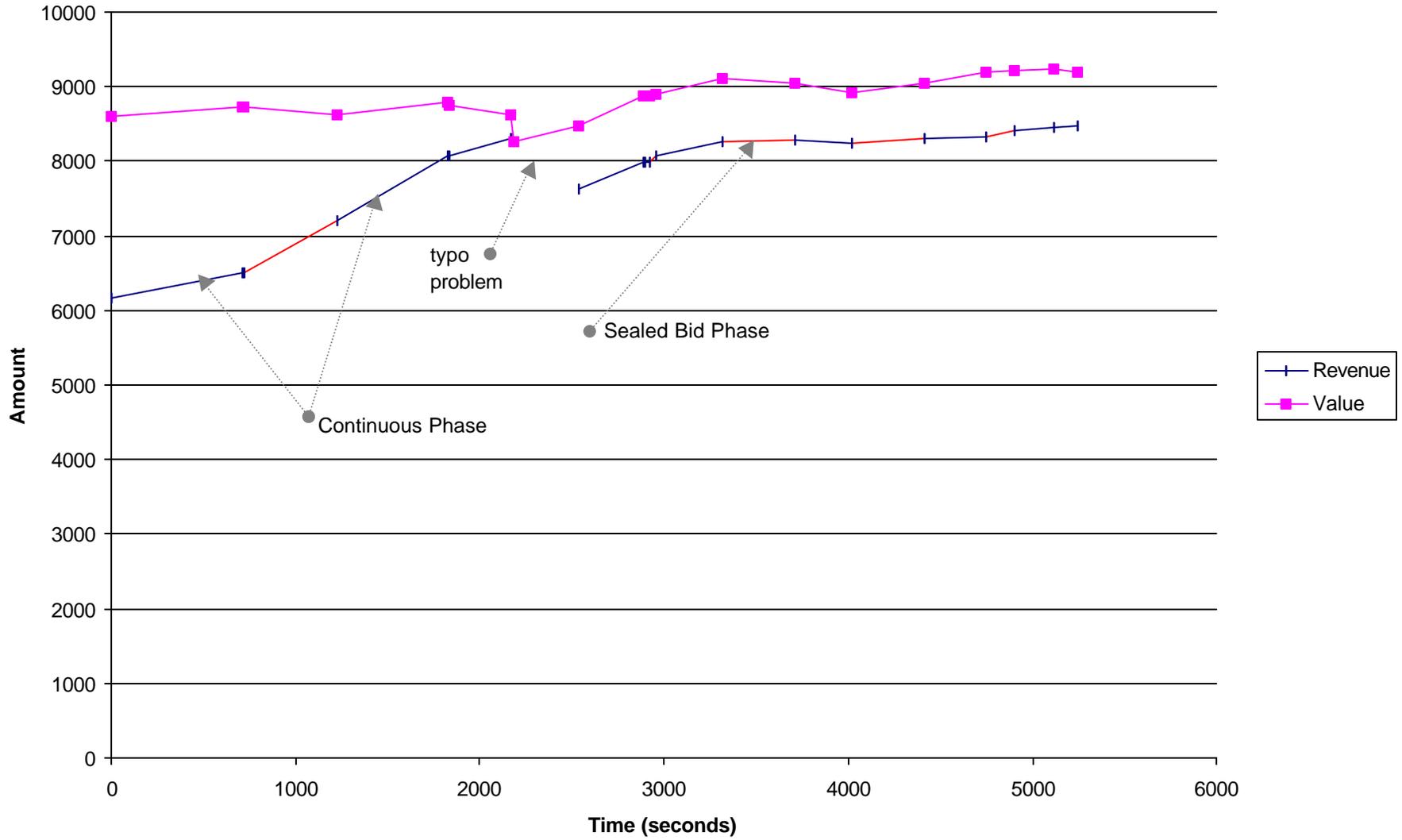
CONCLUSIONS

- **TECHNICAL DEVELOPMENT AND IMPLEMENTATION IS SUCCESSFUL**

- **PARTICIPATION IN THE MECHANISM IS WELL WITHIN THE CAPACITY OF HUMANS**

- **EFFICIENCIES ARE HIGH (90%)**

- **BEHAVIOR OF PRICES AND FLOWS ARE REASONABLY APPROXIMATED BY THE COMPETITIVE MODEL WHEN THE COMPETITIVE EQUILIBRIUM EXISTS**

- **DYNAMIC PRICE AND QUANTITY ADJUSTMENTS ARE ORDERLY**

- **DIFFICULT CASES CAUSE NO PROBLEMS**

SUCH INEFFICIENCIES THAT DO

19990625-2

vealed) ID: [ ]

ce: [ ]

	License	
loc.	1	2
a	☐	☐
b	☐	☐
c	☐	☐
d	☐	☐
e	☐	☐
f	☐	☐
g	☐	☐
h	☐	☐
i	☐	☐
j	☐	☐
k	☐	☐

Submitted

has been submitted

D2 E2 F1

represents **400** bidding units

Total Revenue: 1149

Winning Bids (Bid Number)   **Best Single Item Bids (by Amount)**   **Approximate Item Prices**

	license			license			license			license			license			license	
location	1	2	loc.	1	2	loc.	1	2	loc.	1	2	loc.	1	2	loc.	1	2
A	55	10	a	110		A	15	2	a			A	16	2	a	0	0
B	55		b		40	B	3		b			B	56	0	b	0	253
C	55	57	c	10	40	C	18	15	c	132		C	21	15	c	132	0
D	55	55	d	40		D	41		d			D	43	59	d	0	0
E			e		110	E			e			E	0	0	e	0	0
F	40		f		40	F			f			F	38	0	f	0	0
G			g	40	110	G			g			G	0	0	g	0	0
H	55		h		110	H			h			H	105	0	h	0	0
I			i			I			i			I	0	0	i	0	0
J	27		j			J	5		j			J	5	0	j	0	0
K		40	k			K		2	k			K	0	2	k	0	0
L			l			L			l			L	0	0	l	0	0
M			m	110	40	M			m			M	0	0	m	90	40
N			n			N			n			N	0	0	n	0	0
O		40	o			O			o			O	0	0	o	0	0
P			p	40	10	P			p			P	0	0	p	0	45
Q			q	10	40	Q			q			Q	0	0	q	90	0
R		40	r	40	110	R			r			R	0	2	r	55	0
S	40		s			S			s			S	0	0	s	0	0
T	40		t	110	10	T			t			T	0	0	t	0	0

A	B

#2 will pay 75 for either but only wants one.
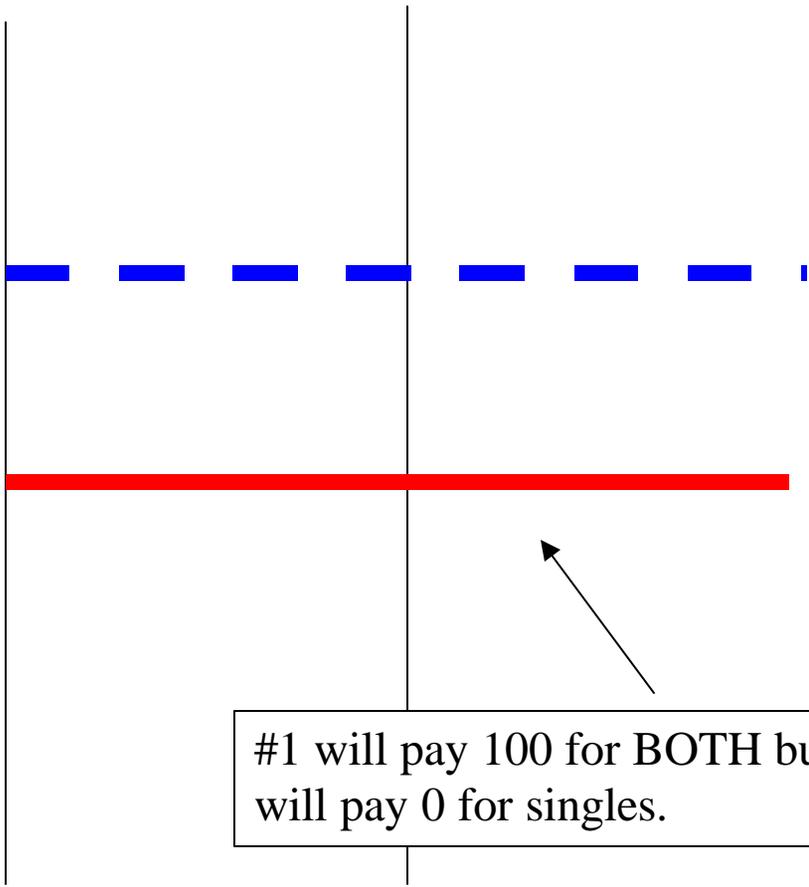
#1 will pay 100 for BOTH but will pay 0 for singles.

cash
Z

$1.75

$1.25

Y

X
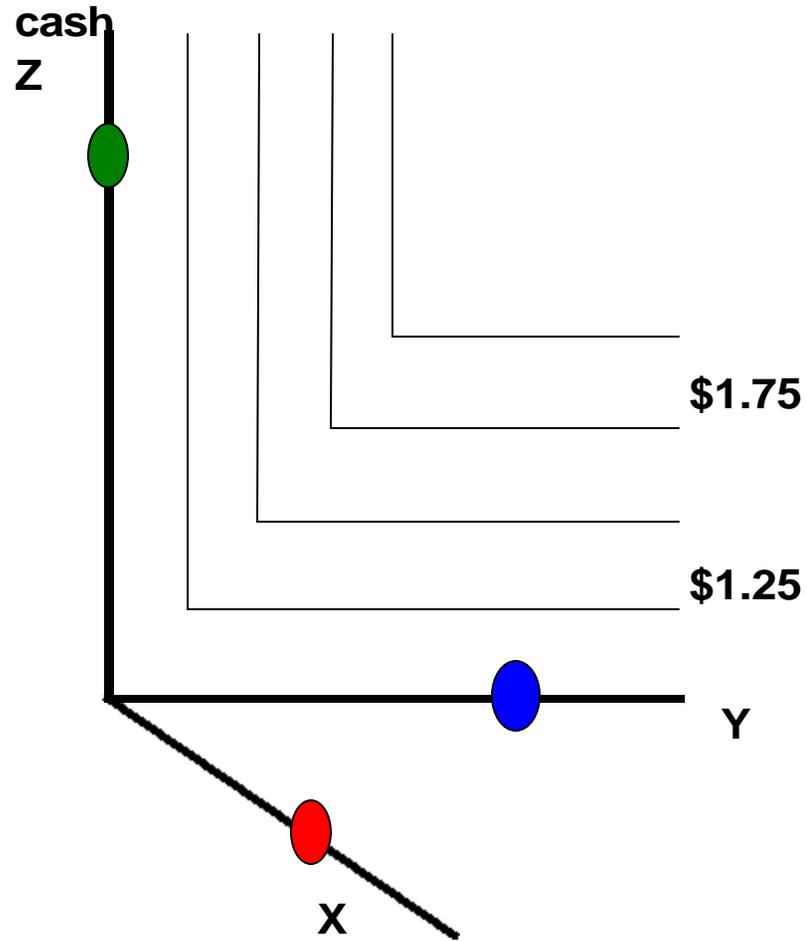
	TYPE 1	TYPE 2	TYPE 3
COUNTER CLOCKWISE	(0,20,0)	(0,0,400)	(10,0,0)
CLOCKWISE	(0,0,400)	(10,0,0)	(0,20,0)
STABLE	(10,0,0)	(0,20,0)	(0,0,400)
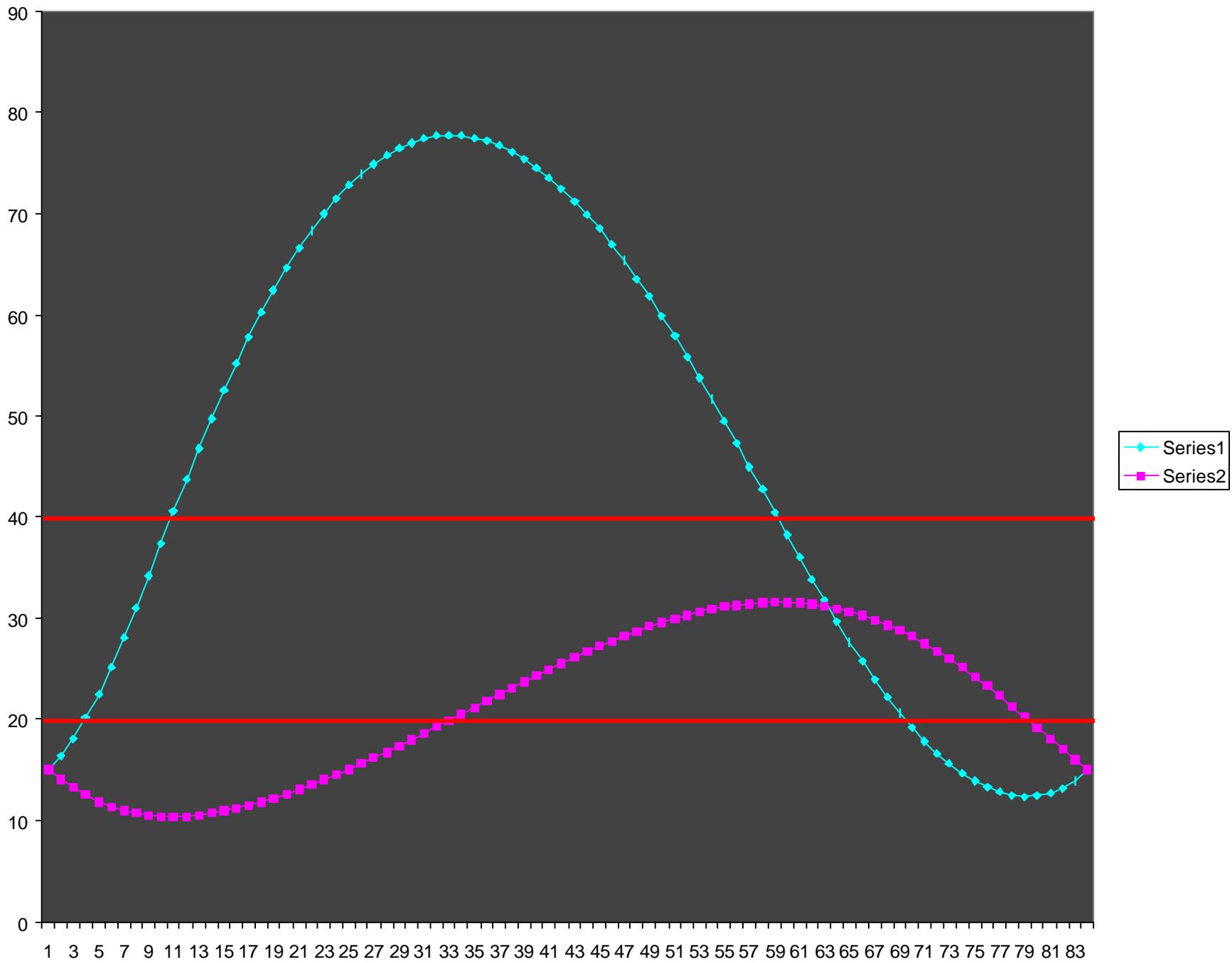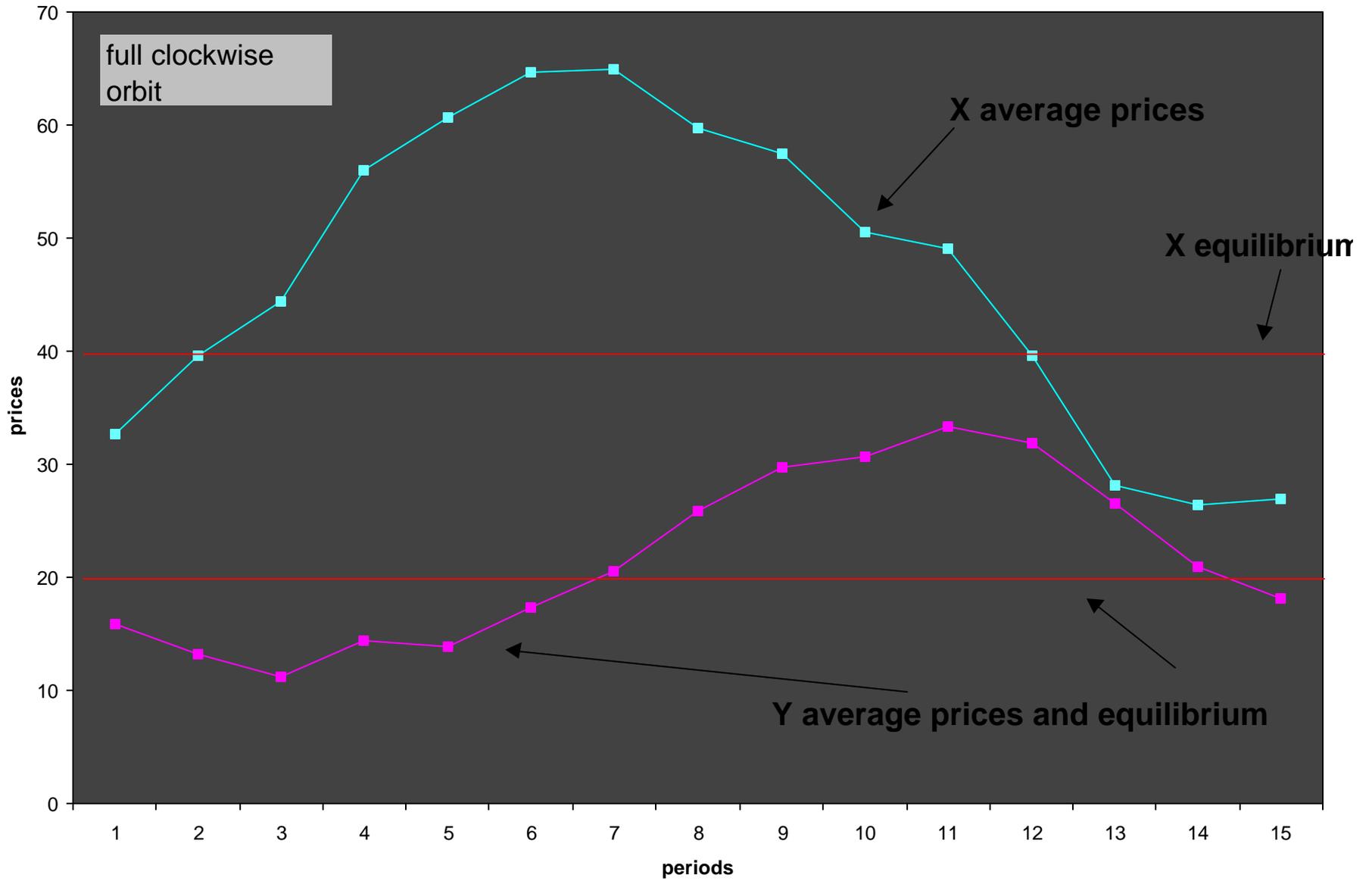
5/11/99 CCW-Experienced
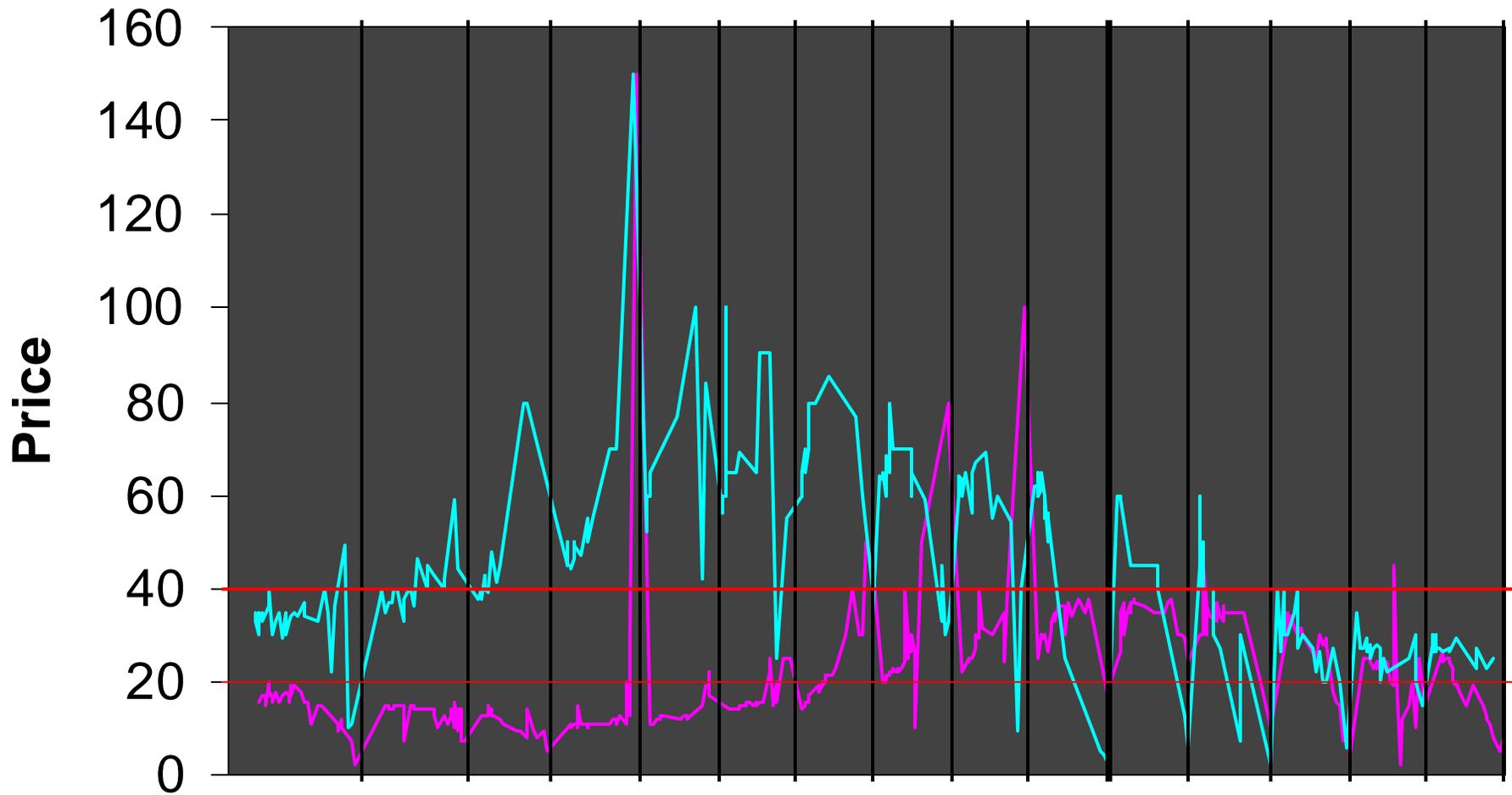
SUBMISSION RULES

A. Every bid must meet an increment requirement.

B. Outstanding bids must meet two eligibility constraints based on individual item weights (bidding units).

   1. Package bids place computational burdens on the system. Encourage only the most "important". Weighted sum of package bids must be less than or equal to eligibility. Weight of a package is sum of weights of items in package.
   2. Total exposure of bids cannot exceed eligibility.

C. Eligibility of a round is determined by the activity of previous rounds.

   1. $E(t+1) = \lambda \min\{E(t), \text{Round activity } (t)\}$
   2. Round activity $(t) = \text{Max}\{\text{sealed activity, continuous activity}\}$
   3. Activity is attributed differently according to the aggressiveness of the bid:
      High enough to be provisionally winning
      High enough to be above the maximum on singles
      At or below the maximum of the singles (get nothing)